THE IMPACT OF INDUSTRIAL LANDUSE ACTIVITIES ON GRASS SHRIMP POPULATION METRICS

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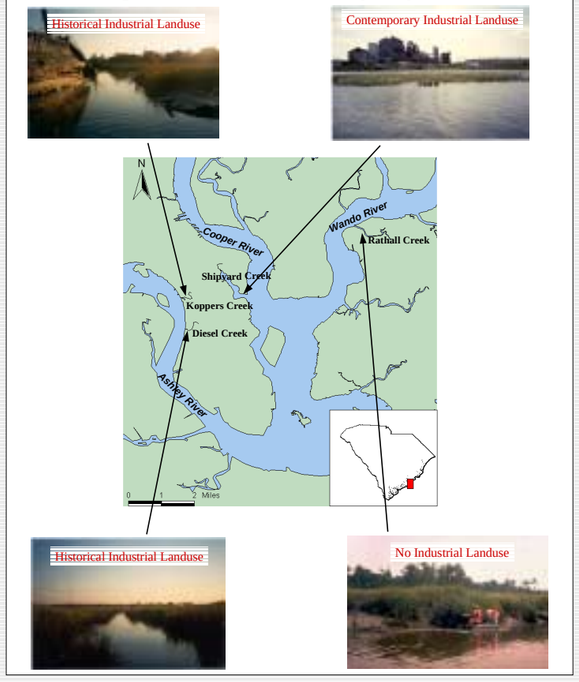
Abstract

The grass shrimp, *Palaemonetes pugio*, is an important component of estuarine ecosystems, making up >55% of the macrofaunal density in estuarine tidal creeks. They facilitate the breakdown of detritus and serve as a key prey item for many ecologically and recreationally important fish species. Significant reductions in grass shrimp density and biomass have been reported in areas adjacent to urban and agricultural landuse activities. This study was designed to evaluate the potential impact of industrial landuse activities by monitoring grass shrimp population metrics in four tidal creeks of the Charleston Harbor estuary, Charleston, SC. Three of the creeks (Shipyard, Diesel, and Koppers) have significant levels of sediment contamination due to historical and contemporary industrial landuse activities. The fourth creek, Rathall, has no history of industrial development and was used as a reference site. Nine 25-m stretches were sampled in each creek monthly for one year with pushnets. Measurements of grass shrimp density, size, and reproductive endpoints (ie. sex ratios, number of eggs per gravid female) were made for all samples. Sediment samples were collected from each site and analyzed for metals, pesticides, polycyclic aromatic hydrocarbons (PAHs), and polychlorinated biphenyls (PCBs). Results indicated that the most heavily contaminated site, Shipyard, had significantly reduced densities relative to the reference site. Densities at the other two contaminated sites (Diesel and Koppers) were not different from the reference site. Grass shrimp size, however, was reduced at these two sites. No significant site-related differences in population sex ratios or clutch size were observed. The findings indicate that a variety of grass shrimp population metrics may be impacted by contaminants associated with industrial landuse.

Introduction

The grass shrimp, *Palaemonetes pugio*, represents an important component of estuarine systems along the southeastern coast of the United States, with populations constituting as much as 56% of the overall stream macrofaunal density (Scott et al., 1992). They facilitate the breakdown of detritus and serve as a key prey item for many ecologically and recreationally important fish species.

Figure 1. Charleston Harbor Estuary Study Sites



This study was designed to evaluate the potential impact of industrial landuse activities on sensitive marsh macrofauna by monitoring grass shrimp population metrics in four tidal creeks of the Charleston Harbor estuary, Charleston, SC (Figure 1). Three of the creeks have significant levels of sediment contamination due to historical (Diesel and Koppers Creeks) and contemporary (Shipyard Creek) industrial landuse. The fourth creek, Rathall, has no history of industrial development and was used as a reference site.

Methods

- Grass shrimp, *Palaemonetes pugio*, were collected by dipnet from nine 25-m stretches in each creek monthly for one year (June 1997 - May 1998).
- Measurements of grass shrimp density, size, and reproductive endpoints (ie. sex ratios, number of eggs/gravid female) were made.
- Sediment samples were collected from each site and analyzed for metals, pesticides, polycyclic aromatic hydrocarbons (PAHs), and polychlorinated biphenyls (PCBs).
- Mean contaminant concentrations were compared with sediment quality guideline levels for threshold (ERL) and median (ERM) biological effects levels.
- Estimates of overall site contaminant levels, Mean ERM Quotients, were calculated by summing the individual analyte ERM quotients for each site and dividing by the number of analytes examined.

Results: Chemistry

- In general, inorganic contaminant levels were higher at Shipyard Creek, while organic contaminant concentrations were highest in Diesel Creek (Table 1).
- Shipyard Creek had the most ERL and ERM exceedences (7 ERL exceedences, 1 ERM exceedence).
- Rathall Creek, the reference site, had the fewest exceedences of sediment quality guidelines (2 ERL exceedences).
- Shipyard Creek had the highest Mean ERM Quotient at 0.34, while Rathall Creek had the lowest at 0.08 (Table 1).

Table 1. ERL and ERM exceedances for inorganic and organic contaminants, and Mean ERM Quotients at grass shrimp sampling sites .

COMPOUND	RATHALL	DIESEL	KOPPERS	SHIPYARD	ERL/ERM
Inorganics					
Arsenic	19.33	22.50	21.27	10.51	8.2/70
Cadmium	0.06	0.31	0.32	0.81	1.2/9.6
Chromium	79.07	91.57	96.50	1815.00	81/370
Copper	23.67	55.53	56.97	37.65	34/270
Lead	33.00	85.17	73.97	73.90	46.7/218
Mercury	0.11	0.11	0.13	0.15	0.15/0.71
Nickel	26.67	26.50	25.87	37.65	20.9/51.6
Silver	0.06	0.23	0.19	0.15	1.0/3.7
Zinc	93.60	151.33	185.00	237.00	150/410
Organics					
Acenaphthene	11.67	59.53	32.77	27.65	16/500
Acenaphthylene	1.60	4.23	4.82	5.77	44/640
Anthracene	28.17	989.93	90.47	41.60	85.3/1100
Fluorene	5.66	28.43	16.87	11.20	19/540
2-Methylnaphthalene	38.70	75.63	48.77	73.75	70/670
Naphthalene	45.10	164.00	88.85	66.83	160/2100
Phenanthrene	24.73	133.87	73.60	95.60	240/1500
Benzo(a)anthracene	15.88	193.00	94.23	156.00	261/1600
Benzo(a)pyrene	32.20	201.33	149.33	150.50	430/1600
Chrysene	16.67	275.33	142.27	200.00	384/2800
Dibenz(a,h)anthracene	14.95	24.67	22.07	20.60	63.4/260
Fluoranthene	62.17	451.33	342.00	253.00	600/5100
Pyrene	45.67	517.33	361.33	253.00	665/2600
Total PCBs	0.3	4.9	1.6	16.1	22.7/180
Total DDTs	0.00	1.69	1.37	2.50	1.58/46.1
>ERL	2	12	8	10	
>ERM	0	0	0	1	
Mean ERM Quotient	0.08	0.18	0.13	0.34	

ERL exceedence ERM exceedence

Results: Grass Shrimp Population Metrics

- Grass shrimp densities at Shipyard Creek were significantly reduced on an annual basis and for 10 of the 12 months sampled, in comparison to the reference site, Rathall Creek (Table 2).
- Annual grass shrimp densities at Diesel and Koppers Creeks were not significantly different from the reference site. Few monthly differences were found, as well, for Diesel and Koppers Creeks when compared to Rathall Creek. (Table 2)
- Grass shrimp size (length and weight) was significantly reduced at Diesel and Koppers Creeks on an annual basis and for most months, when compared to Rathall Creek (Tables 3-4).
- Grass shrimp size (length and weight) was not significantly reduced for Shipyard Creek on an annual basis, and for most months, when compared to Rathall Creek (Tables 3-4). However, the reduced densities at Shipyard Creek likely effected the statistical comparison of Shipyard Creek to Rathall Creek for all other population metrics.

Table 2. Grass shrimp density (# per m^3) estimates at tidal creek study sites. Highlighted values are significantly different ($p<0.05$) from Rathall Creek

Month	Rathall		Diesel		Koppers		Shipyard	
	Mean	Median	Mean	Median	Mean	Median	Mean	Median
January	0.2	0.0	0.7	0.2	0.5	0.4	0.0	0.0
February	1.4	0.6	5.0	2.0	1.2	0.6	0.2	0.2
March	3.0	3.0	1.2	0.6	3.0	0.8	0.0	0.0
April	20.2	20.6	69.4	73.0	0.9	8.2	1.4	0.8
May	18.7	14.8	105.8	101.8	32.8	22.4	1.6	1.0
June	15.8	9.6	21.5	13.4	2.6	1.6	0.4	0.0
July	29.8	31.2	14.2	5.8	10.5	7.0	17.1	0.6
August	8.1	2.6	18.9	10.0	7.0	6.0	0.4	0.2
September	102.1	92.8	8.1	4.0	12.1	11.0	0.3	0.0
October	20.3	18.2	2.0	0.8	24.1	19.4	0.2	0.0
November	28.5	12.0	3.8	2.0	1.9	1.8	0.0	0.0
December	2.8	0.6	0.8	0.2	34.8	1.8	0.0	0.0
Annual	20.9	9.4	20.9	3.4	11.6	3.0	1.8	0.0

= Significantly lower than Rathall upper
= Significantly higher than Rathall upper

- No statistical trends in sex ratios or clutch size were detected.

Table 3. Grass shrimp length (mm) estimates at tidal creek study sites. Highlighted values are significantly different ($p<0.05$) from Rathall Creek reference site.

Month	Rathall		Diesel		Koppers		Shipyard	
	Mean	Median	Mean	Median	Mean	Median	Mean	Median
January	25.6	25	22.3	23	21.9	22		
February	25.5	25	25.2	25	22.4	22.5	25.3	23
March	27.3	24	22.0	22	22.4	25		
April	28.3	27	24.7	24	24.4	24	26.9	27
May	27.9	27	26.5	26	27.5	30	27.4	28
June	26.8	27	23.2	23	25.2	25	21.6	21
July	26.7	27	22.5	23	24.7	25	25.8	26
August	24.3	24	20.3	20	23.2	23	21.9	22
September	21.3	22	20.6	21	23.5	23	20.8	20
October	25.2	25.0	22.2	22	25.2	25.0	18.2	17.5
November	25.8	25	21.2	21	24.8	25	22.0	22
December	26.2	27	22.3	22	24.7	25	21.0	21
Annual	25.9	26	23.2	23	24.6	24	25.7	26

= Significantly lower than Rathall upper
= Significantly higher than Rathall upper

Table 4. Grass shrimp weight (mg) estimates at tidal creek study sites. Highlighted values are significantly different ($p<0.05$) from Rathall Creek reference site.

Month	Rathall		Diesel		Koppers		Shipyard	
	Mean	Median	Mean	Median	Mean	Median	Mean	Median
January	146.0	135	107.0	110	101.4	100		
February	145.4	140	150.7	140	106.0	100	180.0	130
March	180.5	170	109.1	110	121.8	120		
April	226.8	170	143.4	130	154.9	130	177.9	160
May	207.1	170	174.8	140	230.9	255	215.2	200
June	190.6	180	157.7	130	180.1	160	123.1	100
July	192.2	180	131.8	120	157.0	140	174.7	160
August	144.7	130	103.2	90	132.3	130	124.7	110
September	101.8	90	95.9	90	137.7	130	97.0	95
October	152.5	130	113.1	100	156.8	140	61.7	45
November	165.3	150	98.9	90	142.7	130	115.0	115
December	182.9	170	111.7	100	140.7	130	100.0	100
Annual	173.0	150	134.0	120	157.0	130	175.0	160

= Significantly lower than Rathall upper
= Significantly higher than Rathall upper

Discussion

In general, sediment contamination, based on both individual analyte concentrations (ERL and ERM exceedences) and overall site contamination (Mean ERM Quotient), paralleled impacts on *Palaemonetes pugio* populations. The creek with the heaviest contamination, Shipyard Creek, contained the most impacted grass shrimp population. The precise explanation for the reduced grass shrimp size at Diesel and Koppers Creeks remains unclear. However, it is possible that the increased contaminant concentrations at these sites may be responsible for chronic impacts on growth and/or longevity in these populations.

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